U. S. STEEL MINNTAC

TWIN LAKES WILD RICE RESTORATION OPPORTUNITIES PLAN

REVISION 1

AUGUST 2013

PREPARED FOR

U. S. STEEL MINNTAC

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PREPARED BY

NORTHEAST TECHNICAL SERVICES

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1.0 Requirements for the Twin Lakes Wild Rice Restoration Opportunities Plan

As specified by Wetlands Permit No. 2011-00832-JCB, U. S. Steel is required to submit to the U. S. Army Corps of Engineers (Corps) a Twin Lakes Wild Rice Restoration Opportunities Plan within 120 days of permit issuance (December 10, 2012). Details of the requirements are contained in Special Conditions 9 and 10 of the permit as follows:

> 9. You shall submit, within 120 days of permit issuance, a Twin Lakes Wild Rice Restoration Opportunities Plan ("Plan") evaluate and identify implementation alternatives to the reestablishment of wild rice beds within Little Sandy and Sandy Lakes, collectively known as the Twin Lakes. The Plan shall include, but is not limited to, the following activities and appropriate milestones:
>
> > a. A contract scope of work with a qualified aquatic biologist and/or aquatic ecologist with expertise in aquatic habitat restoration to direct development and implementation of the Plan (person(s) with significant expertise in wild rice restoration may also be acceptable);
> >
> > b. A review of relevant information and conclusions from available Minnesota Pollution Control Agency and Minnesota Department of Natural Resource wild rice studies, Tribal wild rice studies and other related studies and research. Relevant information shall include topics of: wild rice habitat, pollution tolerance, restoration, ecology, and historical extent;
> >
> > c. An evaluation which includes an analysis of the hydrology, chemistry, paleobotany, sediment core analysis, and the extent of invasive species of the Twin Lakes, and any other relevant site-specific factors to determine potential success of wild rice restoration within the Twin Lakes;
> >
> > d. An evaluation of property ownership, access, and any approvals (regulatory or otherwise) necessary to undertaking wild rice restoration activities in the Twin Lakes, and;
> >
> > e. The development of a five-year wild rice restoration and monitoring program for those areas of the Twin Lakes that show the greatest potential for restoration based on best information available in the time frame allowed for submitting its report.
>
> 10. Twin Lakes Wild Rice Restoration Opportunities: Plan Implementation: Within 30 days of receipt of the Plan required by Special Condition, the Corps will review the Plan and will set up a meeting between the interested parties for this particular mitigation effort, you, and the Corps to discuss the Plan. Within 30 days following that meeting, the Corps will provide you with written recommendations and comments on the Plan. You shall provide the Corps with and updated plan addressing each of the Corps' recommendations and comments within 60 days of the receipt of the written comments. Upon receipt of the Plan, the Corps will review the plan to determine whether its comments and recommendations have been satisfactorily addressed. If the updated Plan is satisfactory, the Corps will notify you within 10 business days of its receipt of the updated Plan. If the updated Plan is not satisfactory, the Corps will provide additional recommendations and comments and you will provide a revised Plan within 30 days receipt of the Corps' recommendations and comments.
>
> a. The Plan will be initiated no later than October 31, 2013, unless you request, in writing, a request for an extension to Plan implementation. Your request shall include rationale for why the Plan cannot be implemented by October 31, 2013 and a proposed new timeframe for implementing the Plan.

Revision 1 of the Plan is being submitted as required by Special Conditions 9 and 10 of the permit and incorporates comments received from the Corps and interested parties following review of the original Plan, submitted on April 9, 2013. U. S. Steel will work with the Corps to address recommendations and comments on Revision 1 of the Plan. Upon notification from the Corps that the Revised Plan is satisfactory, U. S. Steel will commence work on the Plan. Work on the Plan is contingent upon obtaining all required permits and required property access and timelines will be adjusted accordingly.

2.0 Background Information: Personnel Certification

A team of five (5) professionals in their field have been assembled to complete the Sandy and Little Sandy (Twin) Lakes Wild Rice Restoration Opportunities Plan for U. S. Steel. As required by Special Condition 9(a) of Wetlands Permit No. 2011-00832-JCB, an expert in the field of aquatic habitat restoration has been chosen to guide this work.

Dr. Peter F. Lee, Professor of Biology at Lakehead University, Thunder Bay, Ontario, Canada, is an expert in wild rice habitat requirements and wild rice (WR) propagation. Dr. Lee has spent the majority of his professional career (39 years) completing scientific and laboratory studies concerning environmental conditions influencing WR, and applications of those conditions to establish and manage WR stands. Dr. Lee has worked closely with several private and public entities focused on field-scale WR propagation plans, which included identification of suitable lakes based on water and sediment characteristics, and hydrological components such as water depths and depth fluctuations. Dr. Lee will provide expert guidance and support throughout this project, ensuring proper investigation of WR ecological requirements are considered throughout the duration of this project.

Mr. David Johnson, Northeast Technical Services (NTS), has worked closely with State regulatory agencies and is familiar with current water quality regulations and certain specifics of this project and the Twin Lakes system. Mr. Johnson will be the overall Project Manager of this work, and will primarily serve as a central contact for U. S. Steel personnel regarding project scheduling, progress, and reporting of accomplishments.

Mr. O'Niell Tedrow, M.S., Instructor / Water Resources Scientist at Vermilion Community College, Ely, MN, and NTS, currently works closely with NPDES permit holders in efforts to ensure compliance with permit requirements. Mr. Tedrow has completed large-scale industry-funded toxicology projects, and designed and completed laboratory and field-scale research projects associated with managing problematic algae and restoring critical water resource usages. Mr. Tedrow is trained in freshwater toxicology and experimental design, and will serve as the primary data manager and field-event coordinator for this project.

Mr. Peter Doran, Instructor Vermilion Community College (retired), currently works with NTS on projects associated with biological assemblage monitoring, specifically directed towards macroinvertebrate assemblage sampling, organism identification to lowest possible taxon, and characterization in terms of the HBI and IBI (indices). These projects are in partial fulfillment of current NPDES permit requirements for stream biological assemblage monitoring. Mr. Doran instructed Biology, Human Anatomy and Physiology, Geology, and Meteorology at Vermilion Community College for 33 years, and is also familiar with wetland plant identification (native and non-native). Mr. Doran will serve as an expert for wetland plant identification and as a reference Biologist for the duration of this project.

Mr. Anthony DeMars, PWS, Senior Natural Resource Scientist with NTS, has over 27 years of experience in natural resources management. His experience includes shallow lake restoration, stream assessments, wetland plant community inventories, wetland function and value assessment, and wetland delineation, permitting, and compensatory mitigation. Mr. DeMars has extensive experience with CWA Section 404, Minnesota Wetland Conservation Act, Minnesota Department of Natural Resources (MN DNR) Protected Waters and NPDES Phase II permit programs. Mr. DeMars has spent his professional career working with aquatic systems for public and private entities, and will also serve as an expert for wetland delineation and wetland plant community evaluation.

All personnel currently associated with the Twin Lakes Wild Rice Restoration Opportunities Plan have spent the majority of their professional careers working on field-scale projects associated with management of aquatic systems. Dr. Peter Lee is the expert aquatic biologist / aquatic ecologist associated with this project. Dr. Lee's expert guidance will allow for the effective and efficient planning and implementation of this Plan.

3.0 REVIEW OF RELEVANT INFORMATION RELATED TO WR HABITAT AND ECOLOGY

Wild rice (WR), *Zizania palustris* L., is the only grain native to North America. Its natural distribution includes much of the eastern portion of the continent in northern United States and southern Canada, but the largest natural stands are found in the lake country of northeastern Minnesota, northeastern Manitoba and northwestern Ontario. These Midwestern WR stands are of great importance to the indigenous people and are fiercely protected as a source of nourishment and an important part of their culture (Vennum 1988). Information on the preferred habitat of WR is largely based on research completed within this geographical region.

Potential sources of stress, or adverse influences on WR growth, are fluctuations in water depth, water characteristics (such as sulfate), sediment characteristics (such as sulfide), and competition from aquatic vegetation.

3.1 WATER DEPTH

Water depth can be the primary factor controlling WR production (Aiken et al. 1988). Water depths directly affect WR by influencing its phenological development and indirectly reduce its ability to compete against perennials better able to cope with increased depths.

Phenological development refers to the life stages of higher plants (angiosperms) from germination of the seed until death of the plant either after a single season (annuals), two seasons (biennials), or several growing seasons (perennials). Unlike terrestrial grains, the shoot in WR emerges from the seed before the root (Aiken et al. 1988). WR use this alternate germination strategy because light and carbon dioxide levels limit the early development of the seedling, as opposed to water availability in terrestrial plants. Seedlings rely on the limited food reserves in the seed as it grows toward the surface of the water where light will not be limiting. Photosynthesis will be optimized when light levels are not reduced by the water column and when carbon dioxide levels increase by forty times as the plant emerges into the atmosphere. Phenological development is directly dependent on water depths; that is the greater the water depths, the longer it will take a WR plant to reach the surface (Thomas and Stewart 1969). Additionally, the longer it takes for the plant to reach the surface of the water, the longer it will remain under photosynthetic and respiratory stress, decreasing its likelihood of survival.

Management of WR lakes primarily involves water level control at depths between 0.5 – 1.0 m. Depths are controlled using techniques varying from removal of beaver dams to construction of dams with stop-logs and diversion of water to other water bodies. Water levels should be increased in the fall to prevent the water from freezing to the bottom of the lake and potentially causing desiccation of the WR seed (Aiken et al. 1988).

Water depth within the Twin Lakes system is influenced by upstream inflows, potential groundwater inflow, and downstream beaver activity in the form of several dams. Throughout the course of this study, these influences will be investigated and to the extent possible quantified as sources of influence on water depth within the Twin Lakes system. Downstream beaver influences on water depth will be managed using appropriate dam removal and trapping efforts. Controlling the outflow of water from the Twin Lakes system should result in more stable water depth conditions, which can be managed to promote water depth conditions favorable to WR germination and growth.

3.2 WATER CHARACTERISTICS

Certain water quality characteristics have been described for waters in which WR grows. Lee (1979) in a survey of WR lakes in Minnesota and Ontario found the majority of lakes supporting WR had soft water with average alkalinities of 40 mg l^{-1} and pH levels of 6.9. A second group of lakes with more hard water with mean alkalinities of 80 mg l^{-1} and pH of 7.4. Pip (1984) examined the distribution of 59 species of aquatic macrophytes, including WR, outside and inside the Precambrian shield of central Canada. She concluded the more important water chemistry parameters associated with their distribution to be pH, total dissolved solids and total alkalinity. Chloride, phosphorus, and sulfate concentrations were reported as "…of minor importance in both areas."

Wild rice is generally associated with more oligotrophic waters. Pilsbury and McGuire (2009) attributed losses of WR in Minnesota and Wisconsin to residential and agricultural developments that increased nutrient levels. Ammonia and pH changes were specifically implicated. Reduction in the range of WR has been attributed to human disturbance including water pollution, recreational activities, and water level manipulation (Bennet et al. 2000; Meeker 1996). Whether eutrophication is a causative factor or correlated factor is not known. Jorgenson (2013) showed that WR could grow in both eutrophic waters with seasonal total phosphorus (P) concentrations reaching 1500 µg l^{-1} and non-eutrophic waters with total P concentrations reaching only 170 µg l^{-1}. Although WR distribution may be influenced by water chemistry or at least correlated to water chemistry, WR also affects the water chemistry in which it lives. Lee and McNaughton (2004) showed that water surrounding WR stands contained lower sulfur (S), higher conductivity and calcium (Ca) and iron (Fe) concentrations than open water areas.

Due to potential influences on water characteristics from U. S. Steel tailings basin seepage, an extensive effort to accurately characterize water samples representative of the Twin Lakes system will be completed (see **section 6.3** for specifics).

3.3 SEDIMENT CHARACTERISTICS

Wild rice obtains most of its nutrients from the soil or sediment and it is the nutrients in the rhizosphere of the WR plant that are most affected by plant growth (Jorgenson 2013). Seasonal nutrient concentrations in the WR roots seem to be correlated to those in the stems and leaves (Lee and Stewart 1983) suggesting that soil effects around the roots are translocated to the rest of the plant. Measurements of specific characteristics of sediment and sediment pore water will be obtained as detailed in **Section 6.2**.

Currently, research efforts directed towards answering questions about aqueous sulfate and concurrent sediment-associated sulfide are underway. A portion of this Plan suggests using onsite mesocosms to help determination of any WR seed viability and development potential (**Appendix A**). As a part of this mesocosm work, sediment-associated sulfide will be monitored, specifically following inoculation of mesocosms with formulated and field sediment in an effort to determine "stability" of sediment-associated sulfide.

3.4 AQUATIC PLANT INFLUENCE AND WR RESTORATION

A suitable wild rice (WR) lake should be of sufficient size and water depth (approximately three feet). Test seeding of areas appropriate for WR propagation is often conducted initially followed by full scale seeding. Seeding is done in the fall or the seed can be over-wintered and spread in the spring, but the rice must be kept moist. The most successful lakes have sufficient light penetration into the water column to enable tillering, an organic sediment with sufficient total phosphorus and nitrogen concentrations, and an absence or minimum of plant competition (Lee and Stewart 1983).

A potential problem in WR areas is development of problematic densities of competing aquatic plants, such as narrow leaf cattails, which are tolerant of similar water depths as WR. Specific herbicides may be used to control problematic aquatic plants. Mechanical harvesting of weeds has also been used as a control practice by cutting off culms which supply the rhizomes with oxygen. Cutting or harvesting as a cattail control method has been effective, and is currently being tested in a newly cattail invaded WR area in Ontario in the Seine River near the Minnesota border.

Primary factors limiting the restoration of WR areas have been related to water depth and management of competing aquatic vegetation. Decreasing water depths in lakes that once contained WR has been effective. In some cases, WR seed likely remained in the seed bank due to secondary dormancy (Atkins 1986). In other cases, volunteer WR appeared once competing cattails were removed, such as at Long Point on Lake Erie (Lee 2001). One major restoration project was the re-establishment of southern WR into a contaminated site on Lake Ontario (Lee 2004). The site had also been invaded by carp. Wild rice areas remain, but require enclosures to prevent damage by remaining carp (**Appendix B**).

For this Twin Lakes WR Restoration Opportunities Plan, potential influences from competing aquatic vegetation will be evaluated. This will include an initial aquatic vegetation survey, followed by continued efforts to characterize and evaluate existing aquatic vegetation and its potential influence on WR and planned WR restoration activities.

3.5 WILD RICE POLLUTION TOLERANCE

Under the Class 4A use classification for Agriculture and Wildlife, Minnesota's water quality standard states: *"10 mg / L sulfate - applicable to water used for the production of wild rice during periods when the rice may be susceptible to damage by high sulfate levels." (Minn. R. 7050.0224, subpart 2)*. No other water quality standards in the Minnesota rules exist for the protection of wild rice. Some initial research describing WR in relation to water chemistry are Moyle's (1944; 1945; 1956) descriptions of WR in relation to water chemistry in Minnesota. However, research suggests that other factors may influence the growth and success of wild rice. Moyle suggested that WR was primarily found in waters with a total alkalinity less than 40 mg l^{-1}, pH between 6.8 – 7.0, and a sulfate concentration of less than 10 mg l^{-1}. It is noteworthy that these observations led to the development of Minnesota's regulation concerning the discharge of sulfates. Moyle's observational work has led to a number of studies concerning the importance of sulfate. Paulishyn and Stewart (1970) reported WR growing in Manitoba in waters with sulfate ranging from 2 – 170 mg l^{-1}. Rogalsky et al. (1971) advised that levels of 200 mg l^{-1} sulfate were acceptable for WR paddies. In a study in the Mississippi River in Minnesota, Lee and Stewart (1981) showed that WR grew well in waters with levels of 30 mg l^{-1} and showed that sulfate in the water varied seasonally at one sampling site from 5 – 120 mg l^{-1}.

Controlled experiments that examine the effects of sulfate have also been conducted. The hydroponic solution recommended by Malvich and Percich (1993) uses a sulfate concentration of 48 mg l^{-1}. Using this culture solution, Lee and Hughes (2000) found that early WR development was affected at sulfate concentrations in the range 1200 – 1500 mg l^{-1}. Vicario and Halstead (1968) conducted experiments with rice in culture solutions with sulfate that ranged from 0 to 8800 mg l^{-1}. They observed decreases in weight and height when sulfate in the culture solutions went above 220 mg l^{-1}.

Currently, a debate has been initiated that the problem is not aqueous sulfate, but rather the production of hydrogen sulfide in the sediment related to sulfates in the water column (MPCA 2011). This was much earlier postulated by Grava (1973) and Grava and Rose (1975) who suggested that sulfides could form in WR paddies and adversely affect WR when sulfate was added as a fertilizer as ammonium sulfate, or an algaecide as copper sulfate (Grave 1977).

Other water quality variables have of course also been described for waters in which WR grows. Lee (1979) in a survey of WR lakes in Minnesota and Ontario found the majority of lakes supporting WR had soft water with average alkalinities of 40 mg l^{-1} and pH levels of 6.9. A second group of lakes with more hard water with mean alkalinities of 80 mg l^{-1} and pH of 7.4. Pip (1984) examined the distribution of 59 species of aquatic macrophytes, including WR, outside and inside the Precambrian shield of central Canada. She found the most important water chemistry parameters associated with their distribution to be pH, total dissolved solids and total alkalinity. Chloride, phosphorus and sulfate concentrations were reported as "...of minor importance in both areas." Wild rice is generally associated with more oligotrophic waters. Pilsbury and McGuire (2009) attributed losses of WR in Minnesota and Wisconsin to residential and agricultural developments that increased nutrient levels. Ammonia and pH changes were specifically implicated. Reduction in the range of WR has been attributed to human disturbance including water pollution, boat turbulence and water level manipulation (Bennet et al. 2000; Meeker 1996). Whether eutrophication is a causative factor or correlated factor is not known. Jorgenson (2013) showed that WR could grow in both eutrophic waters with seasonal total phosphorus (P) concentrations reaching 1500 µg l^{-1} and non-eutrophic waters with total P concentrations reaching only 170 µg l^{-1}. Finally, although WR distribution may be affected by water chemistry or at least correlated to water chemistry, WR also affects the water chemistry in which it lives. Lee and McNaughton (2004) showed that water surrounding WR stands contained lower sulfur (S), higher conductivity and calcium (Ca) and iron (Fe) concentrations than open water areas. Additional information related to WR pollution tolerance, and sulfate tolerance in particular, will be included as background data as they become available.

4.0 Wild Rice Historical Extent: Little Sandy and Sandy (Twin) Lakes

According to 1966 documentation (Sternberg and Hope 1966a,b), the distribution of Wild Rice (WR) in Sandy Lake (Figure 1) was described as being extensive at that time. Site maps created following field work associated with Sternberg and Hope (1966a, b) indicate that WR was present "throughout" Sandy Lake. Although the actual acreage was not reported, the stand was reported to be in good condition with "...several boats ricing on the lake." WR was also reported throughout Little Sandy Lake; more dense stand observed in NE corner of lake. Measured water depths ranged from 2.0 – 3.0 feet throughout these lakes (Sternberg and Hope 1966a, b). According to published literature sources water depths of 0.5 – 3 feet are more conducive to WR growth and propagation (MN DNR 2008; Vogt 2012). Historical water depths in Little Sandy and Sandy Lakes have been favorable for WR growth and propagation. Vogt (2012) observed WR plants in Sandy Lake during 2006, 2007 (not a complete survey of lakes; lakes not surveyed during 2008, 2009), 2010, 2011, and 2012 surveys. The density of WR plants observed during each of these surveys was fewer than approximately 100 total plants. According to the report, the number and distribution of WR plants and overall WR density increased each year. WR in Little Sandy Lake was observed only during the 2006 and 2012 surveys. For this Twin Lakes WR Restoration Opportunities Plan, the entire area / volume of the Twin Lakes system will be considered the restoration area.

5.0 Twin Lakes Wild Rice Restoration Plan Objectives

Based on the requirements for this Plan, and comments received from the USACE and Native American Tribal representatives, the overall objective of this Plan is to evaluate the presence and, if present, the viability of an existing WR seed bank in the Twin Lakes system. If an existing seed bank is viable (i.e., existing WR seeds are able to germinate, grow, and reproduce) it will be the intention to use seed from Twin Lakes WR plants for future seeding events within the Twin Lakes as a part of this Plan. If a viable WR seed bank is not identified in the Twin Lakes system, then an acceptable alternative source of WR seed will be identified and used for the remaining components of this Plan.

Within the overall objective of identifying and using any viable WR seed bank from the Twin Lakes system, four specific research foci have been identified: **1)** physical and chemical characterization of representative sediment cores from each of the two lakes (this will include characterization of pore-water from Twin Lakes sediment samples), which will help to identify any constituents of concern, and the presence and viability of an existing WR seed bank; **2)** characterization of water samples representative of the Twin Lakes system, which will help to identify any constituents of concern; **3)** monitoring and management of water depths of the Twin Lakes system in an effort to promote water-depth conditions conducive to WR growth, and **4)** characterization and management of existing aquatic vegetation, which may out compete WR for available resources.

WR distribution and density will be specifically measured twice per year; once mid-Summer (at the time lake sediment cores are obtained, see below), and once during Fall when WR is more likely to be identified in its more mature, reproductive stage. However, observations of WR during other field events (e.g., lake access reconnaissance events, water sampling, sediment sampling, etc.) will be noted; approximate area of existing WR beds will also be obtained. Specific areas in which WR was observed by Vogt (2012) will be visited. This will serve as a continuation of an existing WR distribution and density dataset.

5.1 VIABILITY OF ANY EXISTING WR SEED BANK

Prior to initiating any work associated with WR restoration, determination of an existing WR seed bank, and the viability of any seed therein, must be completed. Both sediment cores and / or grab samples will be used to determine the presence of seed which will be sieved from the samples. Laboratory germination tests will determine WR seed viability. Populations of the seed will have to be "bulked" to obtain sufficient supply to re-introduce into the Twin Lakes. This will involve greenhouse and on-site mesocosms to produce the seed as well as to test the viability of any observed WR seed bank from the Twin Lakes. In the event that an existing WR seed bank is not identified within the Twin Lakes system, alternate WR seed sources will be suggested. One possible source will be seeds obtained from any WR stands / plants downstream from the Twin Lakes system within the Sand River. Depending on the quantity / density of WR seed from this source, additional WR seed from alternate source(s) may need to be obtained. U. S. Steel will work with Tribal representatives to determine acceptable source(s) of WR seed.

The mesocosms will simulate conditions in an ecosystem within experimental containers in a natural environment. They provide a more defensible approximation of field conditions versus growth experiments in controlled laboratory conditions. Mesocosms consisting of 2 m diameter x 1.5 m depth have been successfully used for growing WR (**Appendix A**). This approach will be followed for these mesocosm studies. The mesocosms will be controlled for a maximum water depth of approximately 0.5 m using Sandy Lake water. Sediment will be collected from the Twin Lakes, placed into mesocosms, and seeded with WR. Control treatments will be standard black earth fertilized with slow release fertilizer pellets. The experiment will be set up in randomized block design with 4 blocks (mesocosms) x 2 treatments (Sandy Lake sediment or black earth) x 8 reps / treatment. The mesocosms will be covered with bird netting to prevent damage from herbivores. At the end of the growing season, the plants will be harvested and their growth performance quantified.

The overall hypothesis for this mesocosm study will be: under controlled water depth and sediment conditions, WR seeds will germinate, grow, and mature in formulated and field-collected sediment material. Specific objectives for this mesocosm research are: **1)** determine the viability of any existing WR seed bank in the Twin Lakes; and **2)** if viable, continue controlled / mesocosm seeding events in an effort to "bulk-up" WR plants for future seeding / WR restoration activities in the Twin Lakes system.

The primary concern about using mesocosms to test the viability of WR seeds in this case is stability of sediment characteristics, specifically concentrations of sulfide following disturbance during mesocosm set-up. The specific concern is the possibility of disruption and decrease of sediment-associated sulfide during mixing. This concern can be mitigated by obtaining a time-series of sulfide measurements. Following mesocosm set-up, sediment and sediment pore water can be obtained for sulfide measurement at specific time intervals. These measurements will help to determine if and when sediment material begins to stabilize and become acclimated to mesocosm conditions. Re-acclimation of the sediment microbial assemblage will be the primary influence on sediment-associated sulfide. The reason for this concern is the theory that increased aqueous sulfate can result in increased sediment-associated sulfide, which may adversely influence WR germination, growth, and maturation. Data obtained from this mesocosm study will help support or refute this concern.

5.2 Sediment Testing and Characterization

Possible toxicity of sediment pore-water has been mentioned as a limiting factor for the re-establishment of wild rice in the Twin Lakes. A wild rice bioassay will be developed to determine the presence and viability of wild rice seed in sediment collected from the Twin Lakes. Sediment testing for this Plan will consist of chemical and physical characterization. A minimum of ten sediment cores per lake will be obtained. Sediment cores will be obtained at the initiation of the Plan and at the conclusion of this Plan (during the fifth of five years). The 100-year pollen analysis will be completed at the initiation of this Plan. All sediment samples will be transported to Lakehead University Environmental Laboratory (LUEL) under the direction of Dr. Peter Lee. Measured sediment chemical characteristics will include: acid-volatile sulfide (AVS); total carbon, nitrogen, and sulfur; total Fe, Cu, Zn, Co, Ni, Mn, Mo, Se, As, and B.

A requirement of the bioassay will be that the conditions in the collected pore-water are the same as *in-situ* in the lakes. A likely method of pore-water monitoring is to utilize Rhizons, as used by the MPCA in their current field investigations, to measure sulfides at the lake and in the collected sediment samples used in the laboratory bioassay to determine if changes occurred during transport. Measured characteristics of pore water obtained from sediment samples will include: total sulfide, Na, K, Mg, Ca, sulfate, chlorides, Cu, Zn, Co, Ni, Mn, Mo, Se, As, and B. If these analyses are already being completed by MPCA, their data may be co-opted for use in this WR Restoration Opportunities Plan.

In-situ pore water testing for sulfides will follow the Minnesota State adapted testing protocol as detailed in "Wild Rice Standard Field Surveys 2011 and 2012: Preliminary Report" (February 02, 2013). The State has offered to provide pore water data from peepers collected in the two lakes to a depth of 10 cm. This would not include the complete rooting depth of wild rice but are a fine calibration of changes during the upper 10 cm. In order to examine the complete rooting depth, peepers as described by Jorgenson (2013) would be used. These extend to a depth of 40 cm and are designed to sample each 10 cm depth including the water immediately above the sediment-water interface. Deployment of the peepers is described by Jorgenson (2013). At least three peepers per lake would be sampled during late May, June, July, and August.

The sediment cores will be able to characterize physical and chemical changes in terms of "change over time" and will determine whether a "mining influenced" sediment layer, or range, may be identified. Sediment core(s) for this purpose will be obtained in specific sample containers and transported to LUEL on ice in the upright position. This will allow for analysis of specific sections / depths of sediment in the core. These measurements on a depth basis will help to determine whether **1)** any change of sediment characteristics over time is measureable, and **2)** whether any measureable change of characteristics over time may have contributed to the current decreased density and distribution of WR in the Twin Lakes system.

Factors limiting the interpretation of these data include: unknown influence(s) on microbial assemblages responsible for sediment characteristic changes; unknown sedimentation rate(s) of the Twin Lakes (this will influence sediment and pore-water characteristics in regards to microbial activity); and non-verifiable human activity influencing Twin Lakes' hydrology (i.e., beaver trapping, beaver dam removal). In the case that characteristic(s) of sediment, sediment pore water, or both may be adversely influencing WR germination, growth, and maturation, appropriate mitigation tactic(s) will be evaluated.

5.3 Water Testing and Characterization

Water samples representative of the Twin Lakes system will be analyzed for the same parameters as used by the MPCA's current field survey of WR waters [cations / metals (Na, K, Mg, Ca, Fe, Mn, Cu, Zn, Co, Mo, Al, Ag, As, Ba, Cd, Cr, Ga, Ni, Pb, Rb, Sr)], anions (Cl^-, SO_4^{2-}), alkalinity / dissolved inorganic carbon, total P, total N, NO_3^-, NH_4, dissolved organic carbon, and SUVA (specific ultraviolet absorbance). Upon receipt of initial characterization results, those parameters which are below reporting limits will be eliminated from future analyses. Following initial characterization, subsequent water quality samples will be collected at the inlet and outlet of the Twin lakes, as well as from any identified WR beds. These will be analyzed for parameters found to be above reporting limits from the initial characterization, and the important water chemistry parameters identified by Pip (1984; i.e., sulfate, hardness, pH, specific conductance, total alkalinity, TDS, chloride, and total phosphorus). Specific conductance, temperature, pH, and dissolved oxygen will be measured *in situ* using a Hach® HydroLab sonde. Water samples will be analyzed at a Minnesota State certified laboratory.

Specific objectives of water monitoring events will be **1)** obtain background information on characteristics of water in the Twin Lakes system prior to initiation of WR restoration activities; **2)** based on these characterization efforts, evaluate if one, or more, water characteristics may be adversely influencing WR growth; and **3)** based on this evaluation, evaluate potential for mitigation for potentially problematic water characteristics.

5.4 Water Depth Monitoring and Management

Water depth is a major factor controlling WR production (Aiken et al. 1989). Water depths directly affect WR by influencing its phenological development and indirectly reduce its ability to compete against perennials better able to cope with increased depths. Objectives of this research will be to **1)** remove and manage flow impedances downstream from the Twin Lakes which may cause increases or fluctuations in Twin Lakes water depths; **2)** continuously monitor water depths in the Twin Lakes system to better understand the system water balance; and **3)** promote water depth conditions in the Twin Lakes favorable to WR growth.

Phenological development refers to the life stages of higher plants (angiosperms) from germination of the seed until death of the plant either after a single season (annuals), two seasons (biennials), or several growing seasons (perennials). Unlike terrestrial grains, the shoot in WR emerges from the seed before the root (Aiken et al. 1989). WR use this alternate germination strategy because light and carbon dioxide levels limit the early development of the seedling, as opposed to water availability in terrestrial plants. The young seedling relies on the limited food reserves in the seed as it grows toward the surface of the water where light will not be limiting. Photosynthesis will only be optimized when light levels are not decreased by passing though the water column and when carbon dioxide levels increase as the plant emerges into the atmosphere.

In an effort to better understand the water balance of the Twin Lakes system, additional water depth and flow monitoring will be completed throughout the Twin Lakes system. Flow measurements will be obtained at all identified inflows and outflows of each lake at the frequencies described in the tables below. A pressure transducer capable of continuous water-depth measurements will be deployed at the bridge in the Twin Lakes system; and beaver and beaver dam removal activities will be completed downstream to help with control of water depths in the Twin Lakes system. On-site investigations will also be completed to identify locations at which any seepage from the U. S. Steel tailings basin may be entering the Twin Lakes system. Current groundwater monitoring activities in the Twin Lakes system area will be continued throughout the duration of this Plan. Manual water depth measurements will be referenced to the continuous water depth logger. These data will be used to develop a better understanding of the water balance of the Twin Lakes.

6.0 Wild Rice Restoration Review

A suitable WR lake should be of sufficient size, and water depth should be approximately one (1) meter. Test seeding of areas appropriate for WR propagation is often conducted initially followed by full scale seeding. Seeding is done in the fall or the seed can be over-wintered and spread in the spring, but the rice must be kept moist. Lakes have also been seeded in the winter on the ice but this is not a common practice (Lee 1986). The most successful lakes have sufficient light penetration into the water column, an organic sediment with high total phosphorus and nitrogen concentrations, and an absence or minimum of plant competition (Lee and Stewart 1983).

Management of WR lakes primarily involves water level control at depths between 0.5 – 1.0 m. Depths are controlled using techniques varying from removal of beaver dams to construction of dams with stop-logs and diversion of water to other water bodies. Water levels should be increased in the fall to prevent the water from freezing to the bottom of the lake and causing desiccation of the WR seed (Aiken et al. 1988).

Another potential problem in WR areas is development of problematic densities of competing aquatic plants. Specific herbicides may be used to control problematic aquatic plants. Mechanical harvesting of weeds has also been used as a control practice by cutting off culms which supply the rhizomes with oxygen (Lee 1986a). More problematic has been increased coverage of WR areas by other aquatic vegetation tolerant of similar water depths as WR. Cutting or harvesting as a cattail control method has been effective, and is currently being tested in a recently cattail invaded WR area in Ontario in the Seine River near the Minnesota border.

Primary factors limiting the restoration of WR areas have been related to water depth and competing aquatic vegetation. Decreasing water depths in lakes that once contained WR has been effective. In some cases, WR seed likely remained in the seed bank due to secondary dormancy (Atkins 1986). In other cases, volunteer WR appeared in commercial amounts once competing cattails were removed (Lee 2001). One major restoration project was the re-establishment of southern WR into a contaminated site on Lake Ontario (Lee 2004). The site had also been invaded by carp; WR production was only possible once carp had largely been removed. Wild rice areas remain, but require enclosures to prevent damage by remaining carp (**Appendix B**).

In the case that characteristics of the Twin Lakes system water, sediment, or both are determined detrimental to WR germination, growth, and maturation, appropriate mitigation tactics will be initiated. Beaver trapping and beaver dam removal activities are an ongoing strategy for managing water depths in the Twin Lakes system. According to water characteristic measurements contained in Vogt (2012), and following installation of a surface and shallow groundwater seepage collection system along the base of the U. S. Steel tailings basin near the Twin Lakes system, chemical characteristics of Twin Lakes water are changing. Specifically, measured sulfate concentrations in water samples from the Twin Lakes have decreased by several hundred mg / L between 2010 and 2012. These data suggest that the Twin Lakes system is benefitting from the seepage collection system installed at the base of the U. S. Steel tailings basin. Potential benefits for WR in the Twin Lakes system from this tailings basin seepage collection system have yet to be observed. Due to the continued change in certain water characteristics in the Twin Lakes system from multiple management practices (i.e., beaver management, seepage collection), any change in WR density and / or distribution may not be attributed to any single activity.

7.0 PROPERTY OWNERSHIP, ACCESS ROUTES, AND REGULATORY APPROVALS

7.1 PROPERTY OWNERSHIP

Land ownership on Twin Lakes and the Sand River is a mix of private and federal (USFS). Private land is concentrated on the northeast shore of Sandy Lake and along Sand River for approximately ¾ miles downstream of Sandy Lake. The location and ownership of private land parcels is summarized in **Table 1**.

Table 1. Private Land Ownership on Little Sandy Lake, Sandy Lake, and Sand River

Sec-Twp-Rng	Legal	Owner	Acres	Comments
1-59-18	SW NW	Howard R. Hill	40	Sand R. d/s of lake
1-59-18	NW SW	Howard R. Hill	40	Sand R. d/s of lake
1-59-18	NE SW	Lindae Hendrickson	Part of 80	Sand R. d/s of lake
2-59-18	Gov't Lot 7	Steven L. Miller	50	Sandy Lake
2-59-18	Gov't Lot 8	Howard R. Hill	39.8	Sandy Lake / Sand R

Landowners with riparian lots will need to be informed of WR restoration activities and may need to agree to the proposed plan including seeding of rice, changes to lake level, and other actions that might be taken to restore WR within Twin Lakes.

7.2 ACCESS

CR 308 crosses between Little Sandy and Sandy Lakes via a steel truss bridge which remains in place today. To the south of Twin Lakes, CR 308 terminates at the west line of Section 13, T 59N, R 18W, or approximately two (2) miles from the Twin Lakes bridge. To the north, CR 308 terminates near the NW SE of Section 34, or approximately 1.2 miles from the Twin Lakes bridge. According to Vogt (2012) access from the north along the former CR 308 is flooded in several places and may require the use of chest waders. Land ownership along the abandoned portion of CR 308 is federal.

7.3 REGULATORY APPROVALS

The MN DNR will be consulted for any and all permits related to WR seeding, planting, and any system manipulations such as sediment removal / sampling; design, location, and operation of mesocosm growth trials; beaver dam removal; and animal (i.e., beaver) trapping. Property ownership rights, routes of access, and required permitting activities will be assessed throughout the duration of the study. Updates to these will be added to the Plan as they become available. Depending upon the scope of the restoration project, the applicability of environmental review will also be evaluated.

8.0 PROPOSED TIMELINE OF ACTIVITIES

First Year of the Plan

Estimated time frame [1]	Activity
May	Initial deployment of pressure transducer water depth monitoring instrument(s).
May – October	Obtain water samples at least monthly. Continue water depth measurements at each sampling / monitoring event.
June	Obtain initial sediment core sample(s) for 100-year pollen analysis, chemical characterization, and characterization of any identifiable, existing WR seed bank in the Twin Lakes system. Based on 2012 survey observations, obtain initial characterization of plant assemblages within Little Sandy and Sandy Lakes. Initiate assessment of entire lake areas as potentially suitable for WR restoration. Flow measurements at all identifiable inflows / outflows of each lake.
July – October	Continue observations and documentation of WR beds and existing plant assemblages. Continue monthly inflow / outflow measurements.

[1]Sequencing of activities may be adjusted based on the timing of Corps notification that the Plan is satisfactory.

Second Year of the Plan

Estimated time frame	Activity
May	Secondary deployment of pressure transducer water depth monitoring instruments.
May – June	Initiate onsite mesocosm-scale WR growth studies using formulated and field sediment, and water representative of the Twin Lakes system.
May – October	Collect monthly water quality samples, and water depth and flow measurements. Based on previous observations, continued characterization of the existing plant assemblages including WR bed evaluation. Measurement of surface area of observed WR beds using GPS. Continue evaluation of areas within each lake potentially suitable for WR restoration. Download of water depth data from continuous data logger(s) and manual depth measurements at critical locations during each field sampling/monitoring event.
June	Obtain second sediment core sample(s)

Third to Fifth Years of the Plan

Estimated time frame	Activity
May – October	Continue monthly water sampling, and water depth and flow measurements. Continue characterization of aquatic plant assemblages, including evaluation of areas within each lake potentially suitable for WR restoration.
June	Obtain sediment core sample(s) as required.
Dates to be determined	Conduct WR test seeding events during the year following mesocosm studies. Locations of specific WR test seeding events will be based on observations of existing WR beds, assessment of water and sediment characteristics, and results / observations from WR mesocosm studies. Monitor and document WR test seeding locations during remaining Plan years. Depending upon the results of test WR seeding / restoration, monitoring activities may be reduced / changed during subsequent field seasons.

If no areas have been identified within the Twin Lakes that are potentially suitable for WR restoration, or if test seeding events are unsuccessful following the Fourth year of the Plan, U. S. Steel may terminate the remainder of the Plan. Should this be the case, U. S. Steel will request concurrence from the Corps that there is no potential for the successful restoration of WR in the Twin Lakes and the Plan may be terminated.

Special Condition 10 of the permit requires that U. S. Steel initiate the Plan no later than October 31, 2013 unless a written request for extension is submitted. Condition 9(e) requires the development of a five year Plan. Therefore the Plan will terminate no later than October 31, 2018 unless extensions have been granted. In order to ensure progress on the Plan, work done pursuant to the Plan prior to notification from the Corps that the Plan is satisfactory will be credited to the time requirement of the permit.

9.0 NATIVE AMERICAN TRIBAL SUPPORT

As a part of the overall objective of restoring WR to the Twin Lakes system, Native American Tribal support will be requested. Prior to initiation of any WR restoration work in the Twin Lakes system, a shoreline invocation will be requested from a spiritual elder from one of the regional Chippewa bands. All WR re-seeding activities will be completed using canoes and hand-seeding techniques as recommended by local Native American representatives.

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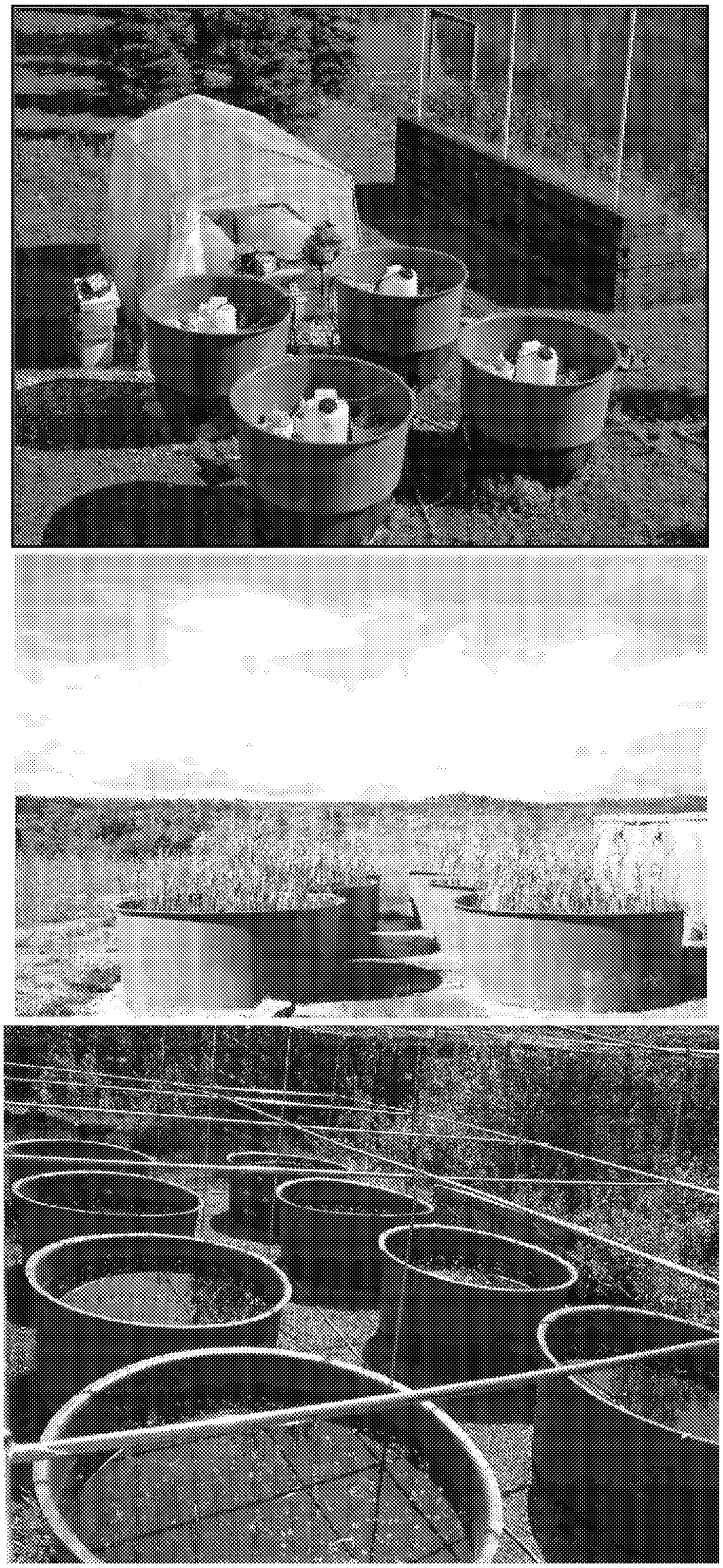
APPENDIX A

ON-SITE MESOCOSM TRIAL IMAGES



On-site mesocosms set-up at a pulp and paper mill (**upper**) and mine site (**middle**). **Bottom**: Additional example of on-site mesocosm arrangement.

APPENDIX B

IN-LAKE TEST SEEDING TRIAL IMAGES

Test seeding / WR Restoration plots: Restoration of southern wild rice into Cootes Paradise, Lake Ontario. Individual enclosures (upper) were joined together (middle), seed scattered within, and resultant stand the following year (bottom).